DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention]The beam splitter in which this invention was formed with the crystalline material, and a wavelength plate, And it is related with the suitable optic for the optical system relevant to the exposure device used when manufacturing micro devices, such as a semiconductor device and a liquid crystal display element, by a photolithography process especially about the optical apparatus provided with these crystal optics parts.
[0002]
[Description of the Prior Art]Formation of the minute pattern of electron devices (micro device), such as an integrated circuit and a liquid crystal display, is faced, The method of carrying out reduction exposure transfer of the pattern of the photo mask (it is also called reticle) which carried out proportionality expansion of the pattern which should be formed at about 4 to 5 times, and drew on photosensitive substrates (exposure substrate), such as a wafer, using a projection aligner is used. In this kind of projection aligner, in order to correspond to the minuteness making of an integrated circuit, that exposure wavelength is continuing shifting to the short wavelength side.
[0003]Now, no less than 193 nm of the ArF excimer laser of short wavelength of exposure wavelengths are going into a utilization stage more, although 248 nm of a KrF excimer laser is in use. The proposal of the projection aligner which uses the light source which supplies the light of the wavelength range called what is called vacuum ultraviolet areas, such as F_2 laser with a wavelength of 157 nm and Ar_2 laser with a wavelength of 126 nm, is also performed. Also by Taikai talkative(NA)-ization of the projection optical system, since high-resolution-izing is possible, not only the development for the short wavelength formation of an exposure wavelength but development of the projection optical system which has a larger numerical aperture is made.

[0004]In this kind of projection optical system, in order to realize high resolution, that residual aberration needs to be suppressed very small. Because of that purpose, the inspection light study system for measuring the residual aberration of a projection optical system is required, and it cannot be overemphasized that it is required that the residual aberration should be suppressed very small also in this inspection light study system itself. About the improvement in the performance of an integrated circuit, especially improvement in working speed, the size homogeneity of the pattern in a circuit is very important. Since it is necessary to make a light exposure uniform for making a pattern dimension uniform, very high illumination homogeneity is required of the illumination-light study system which supplies the illumination light to reticle.
[0005]Thus, to the exposing light of an ultraviolet area with short wavelength, transmissivity and a homogeneous good optical material (lens material) are limited. In the projection optical system which uses an ArF excimer laser as a light source, although it is usable also in synthetic quartz glass as a lens material, since a chromatic aberration cannot fully be amended in one kind of lens material, a calcium fluoride crystal (fluorite) is used for some lenses. On the other hand, in the projection optical system which uses F_2 laser as a light source, an usable lens material is limited to a calcium fluoride crystal (fluorite) as a matter of fact. And it will be limited also for the material of a lens usable to an inspection light study system or an illumination-light study system, and the material of a penetrable optic to fluorite.
[0006]
[Problem(s) to be Solved by the Invention]These days, to ultraviolet rays with wavelength short in this way, it is reported also in the calcium fluoride crystal (fluorite) which is cubic system that a double reflex arises. In an overly highly precise optical system like the projection optical system used for manufacture of an electron device, the aberration produced in connection with the double reflex of a lens material is fatal, and is indispensable. [of adoption of the lens constitution and the lens design which avoided the influence of a double reflex substantially] The use of an optic and the adoption of lens constitution which avoided the influence of a double reflex substantially are indispensable also about the inspection light study system for measuring the residual aberration of the projection optical system.
[0007]This invention is made in view of the above-mentioned technical problem, and is a thing. the purpose -- ** -- even if it uses the crystalline material of birefringence [like], it is providing the beam splitter and wavelength plate which can secure good optical performance without being substantially influenced by a double reflex.
It aims at providing the optical apparatus provided with crystal optics parts like the beam splitter which has good optical performance without being substantially influenced by a double reflex, or a wavelength plate.
[0008]
[Means for Solving the Problem]In order to solve said technical problem, in the 1st invention of

this invention. In a formed beam splitter, as the crystal belonging to cubic system, an incidence direction of light flux to said beam splitter and an injection direction of light flux from said beam splitter, A beam splitter setting up it be mostly in agreement with a crystal axis [100] of said crystal or this crystal axis, and an optically equivalent crystal axis is provided.

[0009]In the 2nd invention of this invention, as the crystal belonging to cubic system, in a formed beam splitter said beam splitter, Have a prism member of a couple of trianglepole shape and in one prism member. Are set up so that a direction of movement of light flux through which it passes may be mostly in agreement with a crystal axis [100] of said crystal or this crystal axis, and an optically equivalent crystal axis, and in a prism member of another side. A beam splitter setting up so that a direction of movement of light flux through which it passes may be mostly in agreement with a crystal axis [111] of said crystal or this crystal axis, and an optically equivalent crystal axis is provided.

[0010]According to the desirable mode of the 1st invention or the 2nd invention, said beam splitter is a polarization beam splitter. As for said crystal, it is preferred that they are a calcium fluoride crystal or a barium fluoride crystal.

[0011]In the 3rd invention of this invention, a wavelength plate, wherein a direction of movement of light flux which passes said wavelength plate is set up it be mostly in agreement with a crystal axis [110] of said crystal or this crystal axis, and an optically equivalent crystal axis is provided in a wavelength plate formed as the crystal belonging to cubic system.

[0012]According to the desirable mode of the 3rd invention, it functions as 1/4 wavelength plate to light flux which has a thickness of about 6 cm along a direction of movement of said light flux, and has the wavelength of about 157 nm. Or it is preferred to function as 1/2 wavelength plate to light flux which has a thickness of about 12 cm along a direction of movement of said light flux, and has the wavelength of about 157 nm.

[0013]According to the desirable mode of the 3rd invention, it has an entrance plane almost vertical to a direction of movement of said light flux, and the projection surface substantially leaning to a field vertical to a direction of movement of said light flux. As for said crystal, it is preferred that they are a calcium fluoride crystal or a barium fluoride crystal.

[0014]In the 4th invention of this invention, an optical apparatus provided with at least one crystal optics parts of a beam splitter of the 1st invention or the 2nd invention and the wavelength plates of the 3rd invention is provided.

[0015]In the 5th invention of this invention, an illumination-light study system, wherein a wavelength plate given in any 1 paragraph of the 3rd invention is arranged in an optical path of illumination light is provided.

[0016]In the 6th invention of this invention, an exposure device provided with an illumination-light study system of the 5th invention for illuminating a mask and a projection optical system for forming an image of a pattern formed in said mask on a photosensitive substrate is

provided.

[0017]In test equipment which inspects a projection optical system for forming an image of a pattern formed in a mask on a photosensitive substrate in the 7th invention of this invention, Test equipment, wherein it had an irradiation optical system which irradiates said projection optical system with inspection light and said irradiation optical system is provided with an optical apparatus of the 4th invention is provided.

[0018]

[Embodiment of the Invention]The embodiment of this invention is described based on an accompanying drawing. Drawing 1 is a figure showing roughly the composition of test equipment provided with the crystal optics parts concerning the embodiment of this invention. This test equipment measures the wavefront aberration of a test optical system, for example. Drawing 2 is a figure showing roughly the composition of the exposure device provided with the projection optical system as a test optical system of drawing 1. First, the composition and operation of an exposure device are explained with reference to drawing 2.

[0019]The exposure device shown in drawing 2 is provided with the light source 21 like an ArF excimer laser or F_2 laser, for example. The light flux supplied from the light source 21 is led to the illumination-light study system 23 via the light transmission system 22. The illumination-light study system 23 consists of the bending mirrors 23a and 23b, an unillustrated optical integrator (illumination equalization element), etc. which were illustrated, and illuminates the reticle (mask) 33 with almost uniform illumination. The reticle 33 is held, for example by vacuum absorption at the reticle electrode holder 24, and is constituted by the operation of the reticle stage 25 movable.

[0020]It is condensed via the projection optical system 31, and the light flux which penetrated the reticle 33 forms the projection image of the pattern on the reticle 33 on a photosensitive substrate like the semiconductor wafer 32. The wafer 32 is also held, for example by vacuum absorption at the wafer holder 27, and is constituted by the operation of the wafer stage 28 movable. In this way, the pattern projection image of the reticle 33 can be transferred one by one to each exposure region of the wafer 32 by performing one-shot exposure, carrying out step moving of the wafer 32.

[0021]It is also possible by performing scanning exposure (scan exposure) to transfer the pattern projection image of the reticle 33 one by one to each exposure region of the wafer 32, carrying out relative displacement of the reticle 33 and the wafer 32 to the projection optical system 31. Exposure of the circuit pattern to a actual electron device is faced, Since it is necessary to carry out alignment of the pattern of the following process correctly, and to expose it on the pattern formed at the front process, the alignment microscope 30 for detecting correctly the position of the position detecting mark on the wafer 32 is carried in the exposure device.

[0022]When using F_2 laser and ArF excimer lasers (or Ar_2 laser with a wavelength of 126 nm etc.) as the light source 21, the optical path of the light transmission system 22, the illumination-light study system 23, and the projection optical system 31 is purged, for example with inactive gas like nitrogen or helium. When using F_2 laser especially, the reticle 33, the reticle electrode holder 24, and the reticle stage 25 are isolated with an external atmosphere by the casing 26, and the building envelope of this casing 26 is also purged with inactive gas.

[0023]Similarly, the wafer 32, the wafer holder 27, and the wafer stage 28 are isolated with an external atmosphere by the casing 29, and the building envelope of this casing 29 is also purged with inactive gas. The optic 35 arranged in the optical path of the light transmission system 22 is mentioned later. With reference to drawing 1, the composition and operation of test equipment are explained supposing the case where F_2 laser is used as the light source 21.

[0024]The test equipment shown in drawing 1 is provided with the light source 1 which consists of a solid-state laser and crystals for harmonic generations (or fiber etc.). The light flux which has wavelength almost equal to 157 nm which is the wavelength of F_2 laser is ejected from the light source 1. F_2 laser light source used with an exposure device may be used as the light source 1. The light flux ejected from the light source 1 is deflected by the mirror 2, is expanded with the lenses 3, 4, 5, and 6 which constitute a beam expander, turns into a parallel pencil, and enters into the polarization beam splitter 7. The light flux which enters into the polarization beam splitter 7 is linear polarization which has a plane of polarization along a field parallel to the space of drawing 1.

[0025]Therefore, the light flux which entered into the polarization beam splitter 7 penetrates the polarized light separation plane, and enters into the 1/4 wavelength plate 8. The light flux changed into circular light from linear polarization by operation of the 1/4 wavelength plate 8 forms the condensing point 13C on the virtual body side 13 shown by a figure destructive line via the lenses 9, 10, 11, and 12 which constitute a condenser. A half mirror is served as, the field 12a, i.e., the reference surface, by the side of the virtual body side 13 of the lens 12, and it reflects an incoming beam at a predetermined energy rate. The center of curvature of the reference surface 12a is in agreement with the condensing point 13C.

[0026]In this way, since the incidence angle of the light flux to the reference surface 12a will always be 0 times, after the light flux reflected in the reference surface 12a progresses in a condenser (12, 11, 10, 9), following the same optical path as an incoming beam and is changed into a parallel pencil, it enters into the 1/4 wavelength plate 8. On the other hand, the light flux which passed through the virtual body side 13 enters into the optical system 14 (the reference mark 31 shows in drawing 2) which should be inspected, for example, a projection optical system, and forms the condensing point 15C by image formation operation of the

projection optical system 14 on the virtual image surface 15 shown by a figure destructive line. The light flux emitted via the condensing point 15C enters into the lieberkuhn 16 which has a reflector of the sphere form which makes the condensing point 15C a center of curvature.

[0027]The light flux reflected in the lieberkuhn 16 condenses via the projection optical system 14 at the condensing point 13C on the virtual body side 13, after condensing at the condensing point 15C. The light flux through the condensing point 13C enters into the 1/4 wavelength plate 8, after being changed into a parallel pencil by a condenser (12, 11, 10, 9). Thus, the reference beam reflected in the reference surface 12a and the light analysis-ed which went and came back to the projection optical system 14 will return to the 1/4 wavelength plate 8. Here, although both reference beams and light analysis-ed that enter into the 1/4 wavelength plate 8 are circular light, the reference beam and the light analysis-ed which are ejected from the 1/4 wavelength plate 8 are changed into the linear polarization which has a plane of polarization along a field vertical to the space of drawing 1 by operation of the 1/4 wavelength plate 8.

[0028]In this way, it is reflected by the polarization beam splitter 7, for example, the reference beam and the light analysis-ed through the 1/4 wavelength plate 8 are led to the image sensors 17, such as CCD. And the interference fringe of a reference beam and light analysis-ed is formed in the imaging surface of the image sensor 17. Producing this interference fringe according to the difference of the topology of a reference beam and light analysis-ed, the difference of this topology originates in light analysis-ed having gone and come back to the projection optical system 14, and having received the phase change by that wavefront aberration. Therefore, the wavefront aberration of the projection optical system 14 as a test optical system can be searched for by measuring an above-mentioned interference fringe and analyzing the deformation.

[0029]Under the present circumstances, the optical material which the ultraviolet rays of short wavelength [like / with a wavelength of 157 nm which is the wavelength of F_2 laser] penetrate good, and has good homogeneity is limited to fluorite. Therefore, fluorite will be used for the optical material which forms the lenses 3, 4, 5, and 6, the polarization beam splitter 7, the 1/4 wavelength plate 8, and the lenses 9, 10, 11, and 12. In this case, as mentioned above, there is birefringence in fluorite to the light flux of short wavelength. However, about the light which he follows in the direction of the crystal axis [100] of a fluorite crystal, and the direction of a crystal axis [111], birefringence (refractive index difference between two light flux which has a plane of polarization which intersects perpendicularly) is not produced. Therefore, if it sets up so that the crystal axis [111] of a fluorite lens, or [100] and the optic axis AX (as a result, optic axis of a fluorite lens) may be in agreement, a double reflex will be produced to the optic axis AX and the image formation light which he follows to parallel.

[0030]Actually, also in any of the lenses 3, 4, 5, and 6 and the lenses 9, 10, 11, and 12, since the light flux which penetrates the inside has a difference angle (NA), it is slight, but it will be

influenced by a double reflex. Then, with reference to drawing 3, the name of the crystal axis in the crystal of cubic system like fluorite, etc. are explained. Cubic system is the crystal structure which the cubical unit cell arranged periodically in the direction of each neighborhood of the cube. Each cubical neighborhood lies at right angles mutually, and sets Xa axis, Ya axis, and Za axis as this. At this time, the direction of + of Xa axis is the direction of a crystal axis [100], the direction of + of Ya axis is the direction of a crystal axis [010], and the direction of + of Za axis is the direction of a crystal axis [001].

[0031]More generally, when taking a direction vector (x1, y1, z1) in the above-mentioned coordinate system (Xa, Ya, Za), the direction turns into the direction of a crystal axis [x1, y1, z1]. For example, direction of a crystal axis [111] is in agreement with direction of a direction vector (1, 1, 1). Direction of a crystal axis [11-2] is in agreement with direction of a direction vector (1, 1, -2). Of course, in the crystal of cubic system, Xa axis, Ya axis, and Za axis are optically, mechanically, and mutual completely equivalent, and distinction cannot be attached at all in a actual crystal. Each crystal axis into which the row of three numbers and its numerals were changed as shown in a crystal axis [011], [0-11], and [110] is also optically and mechanical completely equivalent (equivalent).

[0032]When this invention needs to define a relative crystal-axis direction strictly, as optically as a crystal axis [011], as shown in [011], [0-11], and [110], numerals and an arranged position are changed, and two or more equivalent crystal axes are written, for example (listing). However, when a relative crystal-axis direction does not need to be defined strictly, it shall have a notation of a crystal axis [011] and an equivalent crystal axis shall be expressed in package optically [plurality as shown in [011], [0-11], and [110]]. This is the same about other crystal axes other than a crystal axis [011], as shown in a crystal axis [001] and [111].

[0033]To the light which he follows in the direction of a crystal axis [100] (or crystal axis optically equivalent to this), and the direction of a crystal axis [111] (or crystal axis optically equivalent to this) among these crystal orientations, a double reflex is not produced as above-mentioned. A double reflex arises to the light which he follows in the direction which is separated from these crystal-axis directions on the other hand. And double refraction quantity serves as the maximum to the light which advances in the direction of a crystal axis [011] (or crystal axis optically equivalent to this). At this time, the difference of the rate n100 of optical refraction which has a polarization direction (the direction of an electric field) in the direction of a crystal axis [100], and the rate n011 of optical refraction which has a polarization direction in the direction of a crystal axis [0-11], If a crystal is fluorite, to the ArF laser light whose wavelength is 193 nm, it is a 3.6×10^{-7} grade, and is a 6.5×10^{-7} grade to the F_2 laser beam whose wavelength is 157 nm.

[0034]In the test equipment of drawing 1, in order to avoid the influence of this double reflex substantially, make the lens 3 and the lens 4 into a lens pair, and let the lenses 9 and 10 be

lens pairs, for example. And while coinciding a crystal axis [111] with the optic axis AX in these four lenses, in each lens pair, relative rotating of one lens is carried out 60 degrees a center [the optic axis AX] to the lens of another side, and it is arranged. Similarly, make the lens 5 and the lens 6 into a lens pair, and let the lenses 11 and 12 be lens pairs. And while coinciding a crystal axis [100] with the optic axis AX in these four lenses, in each lens pair, relative rotating of one lens is carried out 45 degrees a center [the optic axis AX] to the lens of another side, and it is arranged. Thus, it is possible to remove the adverse effect of the double reflex of a fluorite lens substantially by selection of the crystal axis coincided with an optic axis and grant of rotation of the predetermined angle centering on an optic axis.

[0035]On the other hand, since a crystalline material like fluorite will be used also for the polarization beam splitter 7, the wavefront aberration which originates in a double reflex depending on how to take the crystal axis of this crystalline material will occur. Therefore, also in the polarization beam splitter 7, selection of a crystal orientation which the influence of a double reflex does not produce substantially is needed. Drawing 4 is a figure explaining selection of the crystal axis in a polarization beam splitter. Reference of drawing 4 will enter the light flux from the light source 1 (drawing 4 un-illustrating) in the polarization beam splitter 7 along with - Z direction from the method of figure Nakagami. At this time, the incoming beam to the polarization beam splitter 7 is linear polarization which has a plane of polarization parallel to a YZ plane.

[0036]The polarization beam splitter 7 is a cube type (rectangular parallelepiped) beam splitter which consists of triangular prism type the member 7a and the member 7b. And the multilayer film 7c in which S polarization differs in a reflection property and the penetration characteristic from P polarization is formed in the plane of composition of the member 7a and the member 7b. The light flux of P polarization (linear polarization which has a plane of polarization parallel to a YZ plane) which entered into the member 7a along with - Z direction from the method of figure Nakagami penetrates the multilayer film 7c, and enters into the member 7b. And the member 7b is penetrated and it goes to the projection optical system 14 (drawing 4 un-illustrating) to the method of figure Nakashita along with - Z direction.

[0037]On the other hand, the returned light (light analysis-ed) from the projection optical system 14 enters into the member 7b and the multilayer film 7c along with + Z direction from the method of figure Nakashita. At this time, the incoming beam to the polarization beam splitter 7 is linear polarization (S polarization) which has a plane of polarization parallel to XZ flat surface. Therefore, it is reflected in the direction of +Y with the multilayer film 7c, and the light analysis-ed which entered into the multilayer film 7c is led to the image sensor 17 (drawing 4 un-illustrating).

[0038]As mentioned above, in the polarization beam splitter 7, since light flux advances to the 2-way (namely, a Z direction and the direction of Y) which intersects perpendicularly, it needs

to choose a crystal axis which a double reflex does not produce about this 2-way that intersects perpendicularly. The crystal axes which a double reflex does not produce are a crystal axis [100] and a crystal axis ([010], [001], [-100], [0-10], [00-1]) optically equivalent to this. Therefore, in [as this embodiment shows to drawing 4] the polarization beam splitter 7, By setting up so that the incidence direction of light flux and the injection direction of light flux may be in agreement with a crystal axis [100] (or crystal axis optically equivalent to this crystal axis), the adverse effect of the double reflex of a crystalline material is substantially avoidable.
[0039]The light flux which passes along the inside of the member 7a which constitutes the polarization beam splitter 7 by the example shown in drawing 4 is only an incoming beam parallel to a Z direction. Therefore, the member 7a can constitute the polarization beam splitter which is not substantially influenced by a double reflex, even if it sets up so that the incidence direction of light flux may be in agreement with a crystal axis [111] (or crystal axis optically equivalent to this crystal axis). In this case, since the incident side of the member 7a turns into easy <111> sides of processing, it is advantageous in respect of processing of the member 7a, or formation of an antireflection film. At this embodiment, although this invention is applied to the polarization beam splitter 7, it cannot be overemphasized that this invention is also applicable to a mere beam splitter, without being limited to this.
[0040]Subsequently, the 1/4 wavelength plate 8 which uses the crystalline material of cubic system like fluorite is explained. Drawing 5 is a figure explaining selection of the crystal axis in 1/4 wavelength plate. If drawing 5 (a) is referred to, with the 1/4 wavelength plate 8, it is set up so that the direction of movement of light flux may be in agreement with a crystal axis [011] (or crystal axis optically equivalent to this crystal axis). Reference of drawing 5 (b) which is the figure which looked at the 1/4 wavelength plate 8 from the polarization beam splitter 7 side will enter the linear polarization which meets horizontally in the space of drawing 5 (b), and has polarization direction PD.
[0041][then, / in the field which intersects perpendicularly with a crystal axis [011] as shown in drawing 5 (b) (namely, inside of the space of drawing 5 (b))], As in agreement [in a crystal axis [100], [0-11], [-100], and [01-1]] in the direction which makes 45 degrees to polarization direction PD, respectively, the rotation direction (angle of rotation which made the crystal axis [011] coincided with the direction of movement of light flux the center of rotation) of a crystalline material is set up. In this case, the refractive indicees of two polarization which has a plane of polarization in the direction which is separated from polarization direction PD 45 degrees on both sides will differ, and, as for such a crystal optics element, it will have a function as a wavelength plate.
[0042]As mentioned above, the difference of the refractive index of the polarization of the direction of a crystal axis [100] about the light which he follows in the direction of a crystal axis [011], and the refractive index of polarization of the direction of a crystal axis [0-11] is a 6.5x10

-7 grade to F_2 laser beam with a wavelength of 157 nm, when a crystal is fluorite. As a result, the 6.5-nm optical path difference arises to 1 cm of light path length under crystal. Therefore, if the length of the crystal along the direction of movement of light flux is a 24-cm (= 157/6.5) grade, this crystal will function as one wavelength plate. If it is the length whose length of the crystal along the direction of movement of light flux is about 12 cm of 1/the 2, it will function as 1/2 wavelength plate. If it is the length whose length of the crystal along the direction of movement of light flux is about 6 cm of 1/the 4, it will function as 1/4 wavelength plate.
[0043]The 1/4 wavelength plate 8 of this embodiment is based on this principle, and what set the crystal of the fluorite which has above-mentioned crystal orientation as a length of about 6 cm is being used for it as the 1/4 wavelength plate 8. The linear polarization which entered is changed and ejected by circular light by operation of the 1/4 wavelength plate 8 which has the above composition. After penetrating the projection optical system 14, it is reflected in the lieberkuhn 16, and the circular light formed via the 1/4 wavelength plate 8 turns into circular light of the circumference of reverse by this reflection, and enters into the 1/4 wavelength plate 8. At this time, the circular light of the circumference of this reverse is changed into the linear polarization which has a polarization direction in the direction which intersects perpendicularly with polarization direction PD in the space of drawing 5 (b), and is ejected toward the polarization beam splitter 7.
[0044]It cannot be overemphasized that the rotation relation between the outside and crystal orientation may be the gestalt rotated 45 degrees from drawing 5 (b), i.e., the gestalt shown in drawing 5 (c), without limiting the sectional shape of the 1/4 wavelength plate 8 to the gestalt shown in drawing 5 (b). In the test equipment shown in drawing 1, since 1/4 wavelength plate is required as a component, are using the fluorite whose length of the crystal along the direction of movement of light flux is about 6 cm, but. What is necessary is just to use the fluorite whose length of the crystal along the direction of movement of light flux is about 12 cm, without being limited to this, when 1/2 wavelength plate is required as a component.
[0045]The above wavelength plates are important components also in a projection aligner. In a projection aligner, in order to secure the homogeneity of the pattern line width of the circuit pattern to transfer, the illumination-light study system which illuminates reticle (mask) with very uniform illumination is required. However, when using laser as a light source, the homogeneity of illumination will get worse by the interference fringe produced on a mask surface for the high coherence. In order to cancel this, it is preferred that an interference fringe makes it to form a wavelength plate into an illumination-light study system, to control the polarization condition of the light flux from a light source, and be hard to be formed on reticle.
[0046]It is preferred to specifically form 1/4 wavelength plate as shown, for example in drawing 5 as the optical member (crystal optics parts) 35 which consists of a crystalline material belonging to cubic system into the optical path of the light transmission system 22 of a

projection aligner as shown in drawing 2. By this composition, the linear polarization ejected from the laser light source 21 is changed into circular light via the 1/4 wavelength plate 35. As a result, the coherence of illumination luminous flux can be reduced and the interference fringe on the reticle 33 can be reduced by extension.

[0047]Drawing 6 is a figure showing the modification of the crystal optics parts attached into the optical path of a light transmission system of a projection aligner. Reference of drawing 6 constitutes the optical member 35 from the members 35a and 35b which consist of a crystal belonging to cubic system. Here, in the member 35a arranged at the light source side (drawing 6 (a) Nakashita side), the direction of movement and crystal axis [011] of light flux are in agreement like 1/4 wavelength plate shown in drawing 5. And as the member 35a is shown in drawing 6 (b) which is the figure seen from the light source side, As in agreement in a crystal axis [100], [0-11], [-100], and [01-1], the rotation direction (angle of rotation which made the crystal axis [011] coincided with the direction of movement of light flux the center of rotation) of the crystalline material is set up in the direction rotated 45 degrees to polarization direction IP of an incoming beam, respectively.

[0048]Therefore, although the member 35a acts as a wavelength plate, since it differs by the right and left in a figure as the length along the direction of movement of the light flux shows drawing 6 (a), illumination luminous flux will be in the polarization condition which differs by right and left, is ejected from the member 35a, and enters into the member 35b. Here, since the direction of movement and crystal axis [111] of light flux are in agreement in the member 35b, there is no birefringent action. For this reason, while the polarization condition of the light flux which ejected the member 35a had been maintained, it is ejected from the member 35b. Although the emitted light flux from the member 35b illuminates the reticle 33 through the illumination-light study system 23, since various polarization conditions are intermingled in this illumination luminous flux, it becomes possible to suppress generation of the interference fringe on the reticle 33 small enough.

[0049]In this case, the member 35b is not necessarily required. However, it is better to form the member 35b, in order to suppress this refraction since illumination luminous flux is greatly refracted in the ejection end face of the member 35a if there is no member 35b. It cannot be overemphasized that the wavelength plate same also as composition which coincides the direction of movement and crystal axis [111] of light flux in the member 35a by the side of a light source, and coincides the direction of movement and crystal axis [011] of light flux in the member 35b can be formed. In the member of the side which does not produce a double reflex, not a crystal axis [111] but a crystal axis [100] may be coincided with the direction of movement of light flux.

[0050]Although the calcium fluoride crystal (fluorite) is used as an optical material of birefringence in the above-mentioned embodiment, Without being limited to this Other uniaxial

crystals (BaF_2), for example, barium fluoride crystal, A lithium fluoride crystal (LiF), a sodium fluoride crystal (NaF), a strontium fluoride crystal (SrF_2), a beryllium fluoride crystal (BeF_2), etc. can also use other transparent crystalline materials to ultraviolet rays. Among these, the large-sized crystalline material which already exceeds 200 mm in diameter is also developed, and the barium fluoride crystal is promising as a lens material. In this case, it is preferred that crystal-axis directions, such as barium fluoride (BaF_2), are also determined according to this invention.

[0051]By what (exposure process) the pattern for transfer which illuminated reticle (mask) (lighting process) and was formed in the mask in the exposure device of each above-mentioned embodiment using the projection optical system by the lighting system is exposed for to a photosensitive substrate. Micro devices (a semiconductor device, an image sensor, a liquid crystal display element, a thin film magnetic head, etc.) can be manufactured. Hereafter, by forming a predetermined circuit pattern in the wafer as a photosensitive substrate, etc. using the exposure device of each embodiment explains with reference to the flow chart of drawing 7 per example of the technique at the time of obtaining the semiconductor device as a micro device.

[0052]First, in Step 301 of drawing 7, a metal membrane is vapor-deposited on the wafer of one lot. In the following step 302, photoresist is applied on the metal membrane on the wafer of the l lot. Then, in Step 303, exposure transfer of the image of the pattern on a mask is carried out to each shot region on the wafer of the one lot one by one via the projection optical system using the exposure device of each embodiment. Then, in the step 305 after development of the photoresist on the wafer of the one lot was performed in Step 304, By etching by using a resist pattern as a mask on the wafer of the one lot, the circuit pattern corresponding to the pattern on a mask is formed in each shot region on each wafer.

[0053]Then, devices, such as a semiconductor device, are manufactured by performing formation of the circuit pattern of the upper layer, etc. According to the above-mentioned semiconductor device manufacturing method, the semiconductor device which has a very detailed circuit pattern can be obtained with a sufficient throughput. In Step 301 - Step 305, vapor-deposit metal on a wafer, and on the metal membrane, although each process of spreading and exposure, development, and etching is performed, resist, It cannot be overemphasized that each process, such as spreading and exposure, development, and etching, may be performed for resist on the oxide film of the silicon after forming the oxide film of silicon on a wafer in advance of these processes.

[0054]In the exposure device of each embodiment, the liquid crystal display element as a micro device can also be obtained by forming predetermined patterns (a circuit pattern, an electrode pattern, etc.) on a plate (glass substrate). Hereafter, with reference to the flow chart

of drawing 8, it explains per example of the technique at this time. In drawing 8, what is called an optical lithography process of carrying out transfer exposure of the pattern of a mask to photosensitive substrates (glass substrate etc. in which resist was applied) using the exposure device of each embodiment is performed by the pattern formation process 401. Of this optical lithography process, the prescribed pattern containing many electrodes etc. is formed on a photosensitive substrate. Then, by passing through each process, such as a developing process, an etching process, and a reticle peeling process, a predetermined pattern is formed on a substrate and the exposed substrate shifts to the following light filter formation process 402.

[0055]Next, in the light filter formation process 402. The group of three dots corresponding to R (Red), G (Green), and B (Blue) forms the light filter which were arranged by matrix form or was arranged in the group of three filters, R, G, and B, of a stripe in two or more horizontal scanning line directions. [many] And 403 is performed for a cell assembler after the light filter formation process 402. By 403, a liquid crystal panel (liquid crystal cell) is assembled as a cell assembler using the substrate which has the prescribed pattern obtained by the pattern formation process 401, the light filter obtained with the light filter formation process 402, etc. In 403, a liquid crystal is poured in as a cell assembler between the substrate which has the prescribed pattern obtained by the pattern formation process 401, for example, and the light filter obtained with the light filter formation process 402, and he manufactures a liquid crystal panel (liquid crystal cell).

[0056]Then, you attach each part articles in which the display action of the assembled liquid crystal panel (liquid crystal cell) is made to perform, such as an electric circuit and a back light, as a module assembler, and he makes it complete as a liquid crystal display element in 404. According to the manufacturing method of an above-mentioned liquid crystal display element, the liquid crystal display element which has a very detailed circuit pattern can be obtained with a sufficient throughput.

[0057]Although F_2 laser light source which supplies the ArF excimer laser light source and the 157-nm wavelength light which supply 193-nm wavelength light is used in the above-mentioned embodiment, Ar laser light source etc. which supply 126-nm wavelength light, for example can also be used without being limited to this.

[0058]

[Effect of the Invention]As explained above, even if it uses the crystalline material of birefringence like fluorite, for example, by this invention, the beam splitter and wavelength plate which have good optical performance can be realized, without being substantially influenced by a double reflex. In this invention, the optical apparatus provided with crystal optics parts like the beam splitter which has good optical performance, or a wavelength plate can be obtained, without being substantially influenced by a double reflex. The highly precise

test equipment for measuring the wavefront aberration of the projection optical system carried, for example in an exposure device as this optical apparatus, the exposure device which can suppress generation of the interference fringe on reticle small enough, etc. are realizable.

[Translation done.]